EuroSTRATAFORM Numerical Modeling Study of Shelf Stratigraphy and Sedimentation

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LONG-TERM GOALS

The scientific objective of the work is to develop a quantitative understanding of the processes that control the formation of marine stratigraphy over time scales ranging from decades to millennia. This work is based on the creation and application of a series of advanced numerical models representing the dynamics of marine sediment transport, sediment accumulation, morphological change and feedback between the evolving sea floor and the hydrodynamic forcing. Field data are used to both force the models and to verify their results. The models are used to diagnose complex systems and as predictive tools.

The practical objective of the work is to produce and distribute advanced numerical models to a range of researchers and to the SEDFLUX and SEQUENCE model frameworks.

OBJECTIVES

This report covers the work during the final year of a two-year project. The objectives of the second year include:

- Documentation and Access for 3-D SLICE

- Reduction of field data for use with the 3-D SLICE model

- Set-up the 3-D SLICE model for Adriatic Cases

- 3-D SLICE model simulations of Adriatic conditions

- Modeling liaisons

- Manuscripts and meeting.

- Provide a working CST-model to EuroSTRATAFORM researchers including those developing SEQUENCE and SEDFLUX.

APPROACH

The previously developed SLICE model was a 2-DV representation of shelf hydrodynamics and sediment dynamics over a shore-normal vertical section. Thus, it is capable of simulating the development of near-bed stratigraphy in response to time-varying wind, tide, and density field forcing. During the second year of EuroSTRATAFORM this model was converted to a 3-D form. The model is available to the EuroSTRATAFORM community.

A collaboration was developed with the Woods Hole USGS EuroSTRATAFORM group (Chris Sherwood) and Rich Signell (NOPP). They had reduced a large amount of data for winds, waves and hydrographic parameters (salinity-temperature), as inputs to their ROMS model. They kindly provided this data to us along with data time series from one of their model runs. These provided the basis of developing a method to nest the high-resolution 3-D SLICE model into their regional ROMS model. In this way the combined modeling ensemble is capable of simulating the development of near-bottom shelf stratigraphy with considerable detail as it develops in response to the time varying forcing.

The 3-D SLICE model was then used to simulate the observed patterns of shelf sediment distributions and shallow stratigraphy. To accomplish this it was necessary to develop a bottom sediment map for the Italian side of the Adriatic Sea with emphasis on the shelf. Data were obtained from a number of EuroSTRATAFORM investigators, from Chris Jenkins at CSU, and from published sources. These were assembled in an ARCVIEW Geographic Information System. The results have been distributed back to the EuroSTRATAFORM researchers.

In addition to this work, we have continued the distribution of the CST Model to a user community and have developed comparisons between the stratigraphic simulations of this model and those of the more detailed 3-D SLICE model.

WORK COMPLETED

The research of the second year was structured into seven tasks. Table 1 shows the status of this work.

Table 1

Task	Title	Status	Comment
8	Documentation and Access to 3-D SLICE Model	Complete	Completed
9	Field Data Reduction and Assimilation	Complete	Completed
10	3-D Model Set-up for Adriatic Cases	Complete	One basic and 2 variants
11	3D SLICE Model Simulations	Complete	Good agreement with observed shelf sediment patterns
12	Year 2 - Modeling Liason	Complete	Model provided
13	Year 2 - Manuscripts & Meetings	Complete	5 papers, 3 abstracts, 3 conferences
14	Project Administration & Management	Complete	

RESULTS

A considerable part of the effort involved the details of preparing the model boundary inputs based on results from the ROMS model. Although model nesting is not a novel concept it has not, to our knowledge, been accomplished with different event-scale marine sediment dynamics models. Therefore, it was a considerable success when we developed the proper routines to transfer boundary conditions from the interior domain of the regional model. Differences in the form and spatial resolution of the two different grids was the principal obstacle that we overcame.

Comparison of the computed shelf flow fields in the USGS and 3-D Slice model are good. Again we had some initial difficulties but these were solved. Because these comparisons are good we have a direct relationship between the formation of shallow shelf stratigraphy and forcing parameters that can be measured.

The model is reproducing the measured patterns of sediment grain size on the shelf, but blind tests are have not yet been conducted. That is, because we start with a sediment distribution along the boundaries that is derived from measurements, it is not clear whether the model is simply continuing these pattern or if there is adequate tuning of the bottom sediment types and the shelf hydrodynamics for this to be a stable (varying only slightly between events) position of the boundaries between sediment types.

In addition to this work on the 3-D model we have continued to apply the large-scale behavior-oriented CST model to replicating the stratigraphy of the Italian Adriatic shelf. Figure 1 shows a sample result. Here a small mid-Holocene delta is buried within the overall clinoform that now shapes the sea floor.

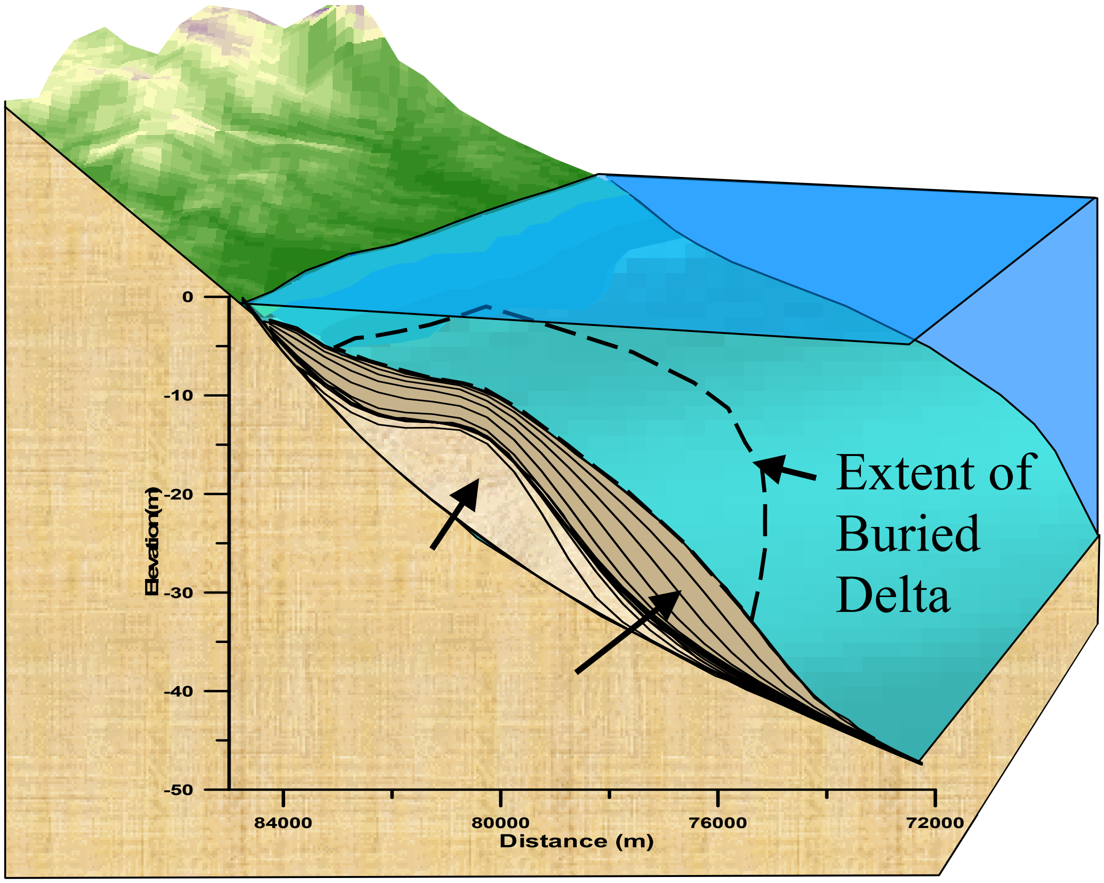

Figure 1 - CST Model prediction of a small delta buried beneath the prograding Holocene shelf clinoform off a typical Apennine watershed river.

The model predicts the existence of this buried delta even though there is no expression of it in the modern shelf bathymetry.

IMPACT/APPLICATIONS

The development of the 3-D version of the earlier SLICE model provides the Navy with the capability of simulating the formation of shallow stratigraphy (upper 1 m) in considerable detail. The bed tracking algorithm keeps track of multiple grain sizes (up to four size classes) so that both the plan and section views of the sediment distributions are represented. Our modeling of the Adriatic shelf has shown that there can be rapid shifts in the surface sediment distribution, but after more than a few centimeters are deposited the sediment compositions at a given point stay relatively constant.

The nesting of the 3-D version of the Slice model provides an important advance in the state-of-the-art in modeling the development of shelf stratigraphy. The principal problem has been to maintain the details of boundary layer interactions and other factors in marine sediment dynamics while operating over a large enough domain to properly represent the shelf hydrodynamics. It is clear from our experience in the Adriatic and the Eel shelf that the scale needed to properly represent shelf hydrodynamics is much larger than the scale of the corresponding sediment dynamics. With the exception of occasional suspended sediment plumes that are usually trapped close to the coast, the shelf sediment moves in a series of weather-event related excursions. By successfully nesting the detailed 3-D SLICE model into the ROMS model we have provided a way of operating over the large scale while preserving the much more detailed grid and sediment dynamics of the SLICE model. Now that this nesting has been completed it is possible to apply this same approach to any of the other large-scale shelf physical oceanography models that are available.

Overall the work accomplished in the second year with the 3-D model combined with the work completed in the first year on the CST-model has resulted in providing the capability of meeting the overall program goals to span the considerable time-scales that need to be addressed in quantitatively predicting shelf stratigraphy in the upper ten meters.

TRANSITIONS

In the second year of this project we have continued work with the U.S. Army Corps of Engineers in developing the 2-DH M-2D model and the 2-DV Channels model. Although the hydrodynamic and sediment dynamic features are similar, there are distinct differences between these codes and the 3-D version of SLICE. At this time it is not deemed appropriate to simply incorporate the 3-D version of SLICE into the U.S. Army Corps of Engineers Surface Modeling System (USACE SMS). Instead, a more sophisticated application of some of this work has been developed for the SMS. The inner-solution of the 3-D version of SLICE is being written into the SMS M-2D model. This will have the effect of making the M-2D model into a true 3D hydrodynamic model. In the near future this 3-D hydrodynamic capability will be put to use by incorporating a suspended sediment transport algorithm. So some of the work in the second year of our EuroSTRATAFORM project is being incorporated into the SMS package but not in a simple manner.

RELATED PROJECTS

This project is part of EuroSTRATAFORM Task D3 – Shelf Transport Modeling and Task D4 – Long-term Stratigraphic Modeling. The work is being carried out in conjunction with other ONR-supported researchers including Courtney Harris, Julie Pullen, John Swenson, Michael Steckler and James Syvitski. In addition we are working with researchers supported by PROMESS (Serge Berne, Xavier Durrien) and EuroDELTA (Gert Jan Weltje, Bavio Trincardi and Antonio Catteneo). This collaboration includes sharing of model code with Michael Steckler (SEQUENCE) and James Syvitski (SEDFLUX). We have also acquired and used data from Serge Berne (Ifremar) and Xavier Durrien (University of Perpigan).

PUBLICATIONS

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